

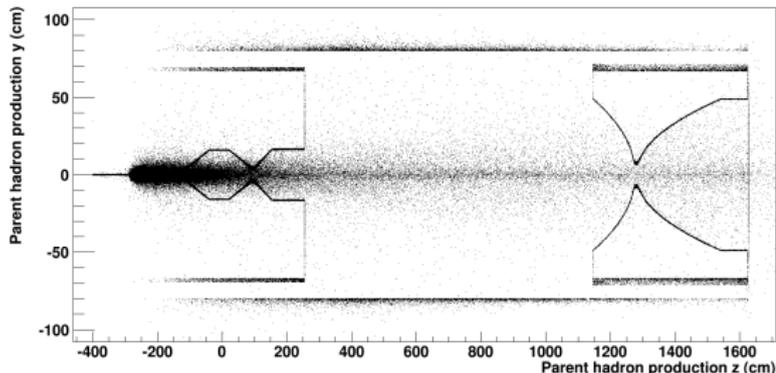
Neutrino Beam Flux in the ND and ND/FD Extrapolation

Mary Bishai

April 5, 2017

- 1** Flux Characteristics
- 2** N/F Extrapolation
- 3** Beam Systematics

- **G4LBNE: v2 compiled with GEANT4-09-05-patch-01 (20-March-2012)**
- **Beam: 80 GeV, $\sigma_x = \sigma_y = 1.655$ mm**
- **Horns: Simplified geometry using LBNO-style 2-horn GA optimization with 297.9 kA, 14.4585m apart**
- **Target: Solid graphite rod: 1cm W x 20.73 cm H x 2.3719m L, $\rho = 1.754$ gm/cm³. Embedded +1cm in Horn 1.**



Flux Components at various ND locations

ND 360

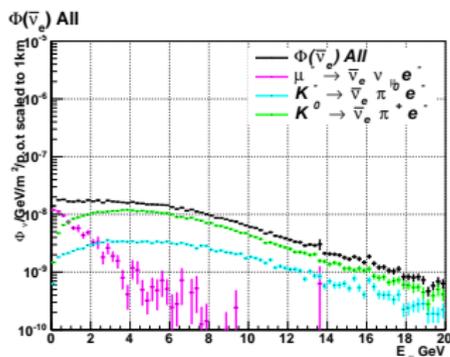
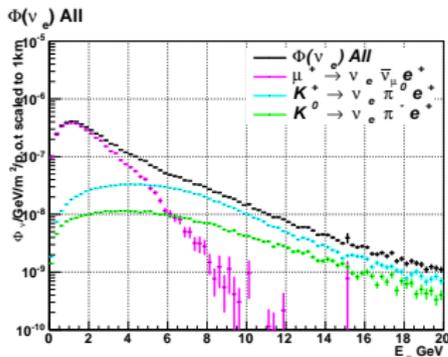
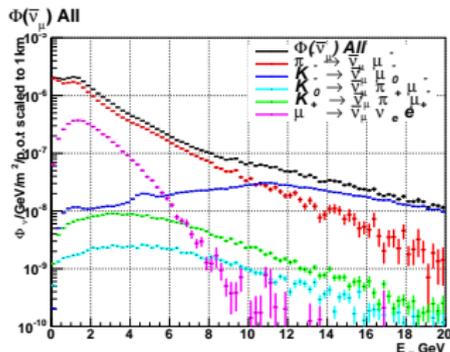
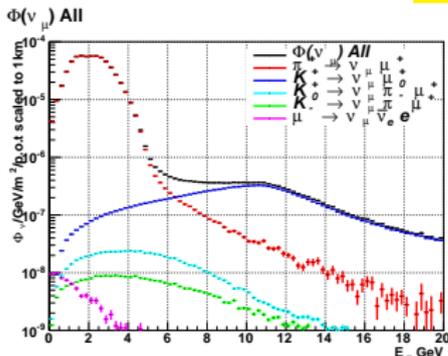
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Flux
Characteristics

N/F
Extrapolation

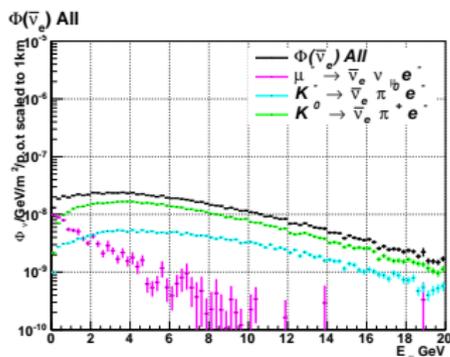
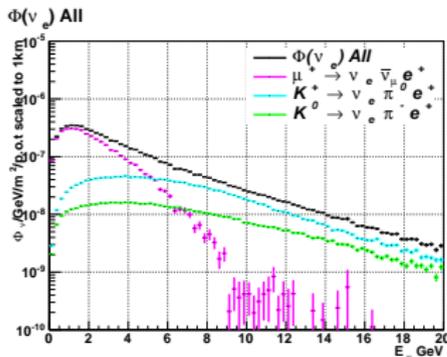
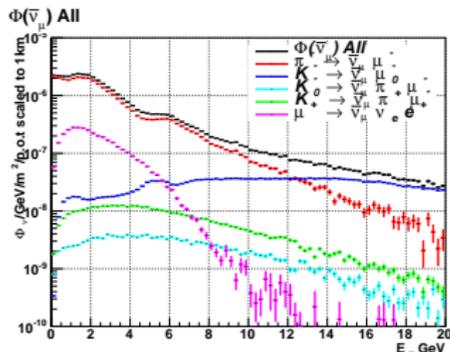
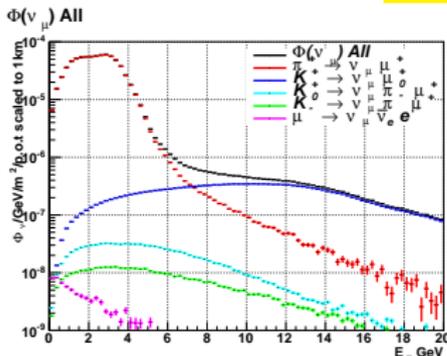
Beam
Systematics



Baseline scaled to 1km from middle of decay channel

Flux Components at various ND locations

FD 1300km



Baseline scaled to 1km from middle of decay channel

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Systematics

Flux Components at various ND locations

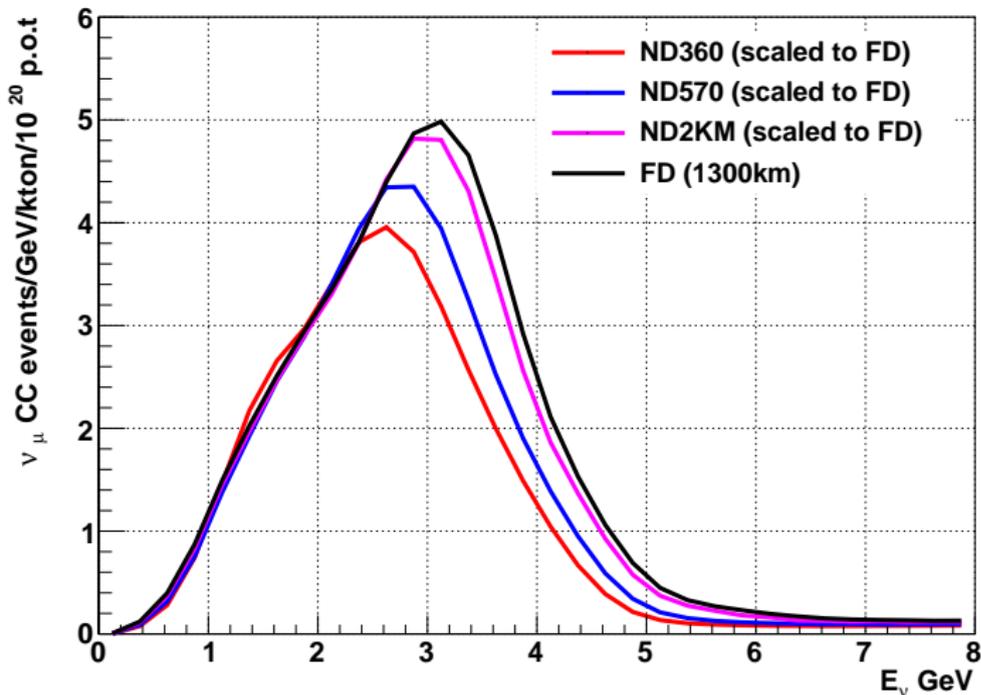
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The ν_{μ} CC spectrum - BL scaled to FD from center of decay channel

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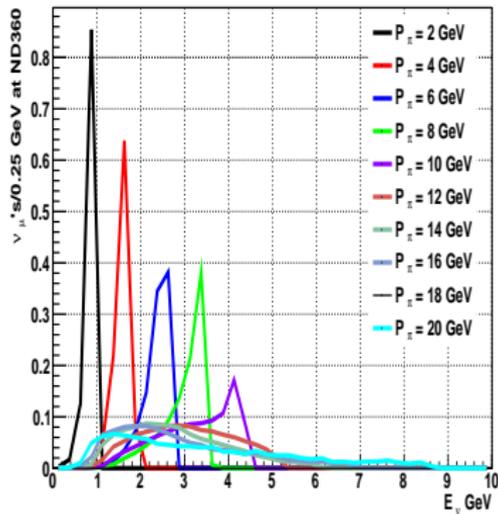
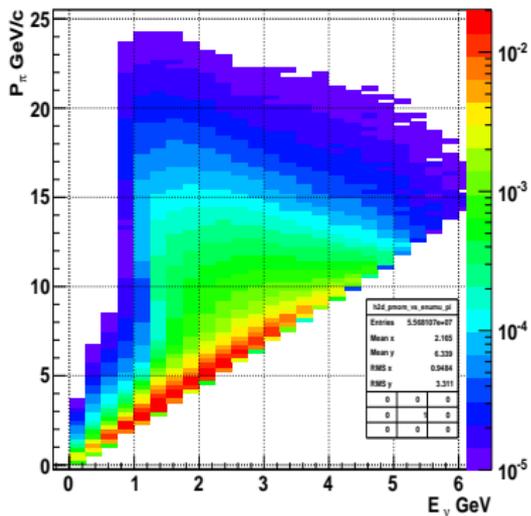
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Flux
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Systematics

Parent momentum vs E_ν π parent



Parent π Momentum vs ν Momentum at ND574

Neutrino
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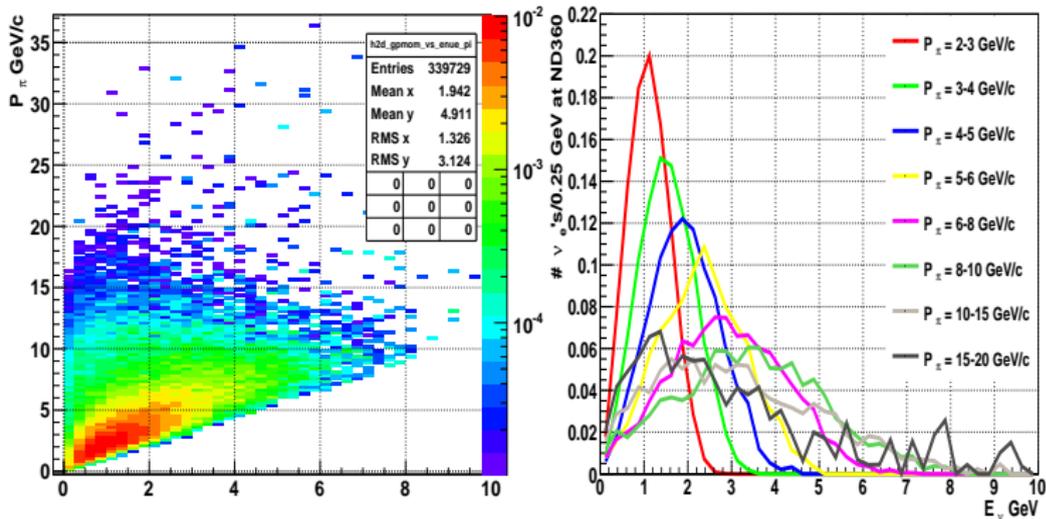
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Flux
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π grandparent momentum vs E_{ν} from μ parent



Origin of Neutrinos (ND570)

Neutrino
Beam Flux in
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Extrapolation

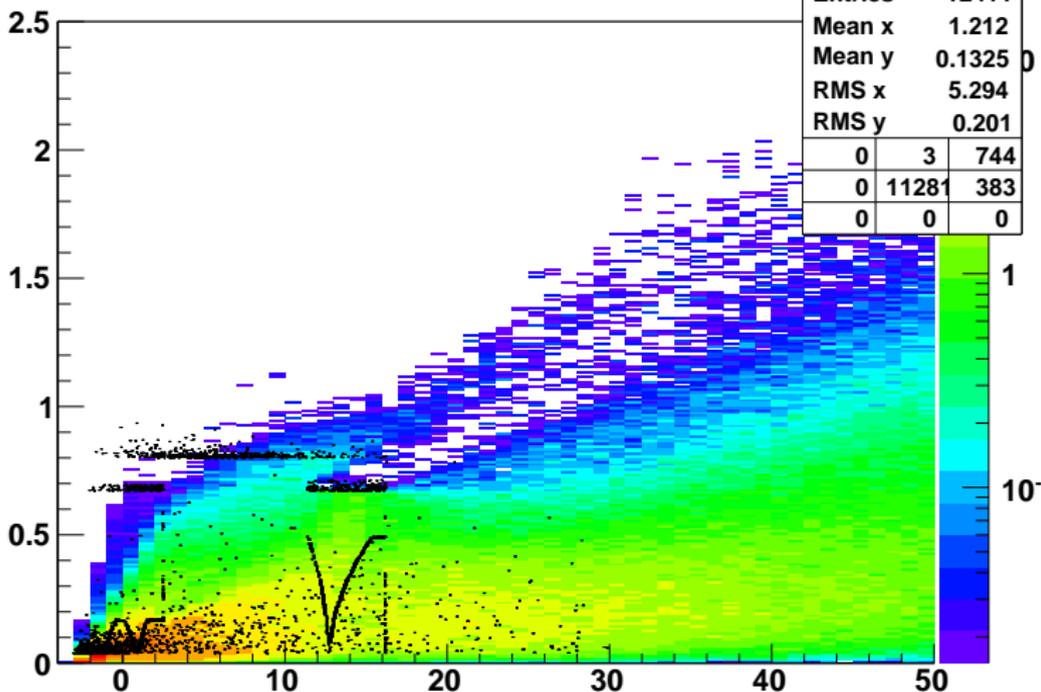
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Flux
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Systematics

ν_{μ} production radius (m) versus $V_z(m)$, $E_{\nu} = 0.5-1.5$ GeV



Origin of Neutrinos (ND570)

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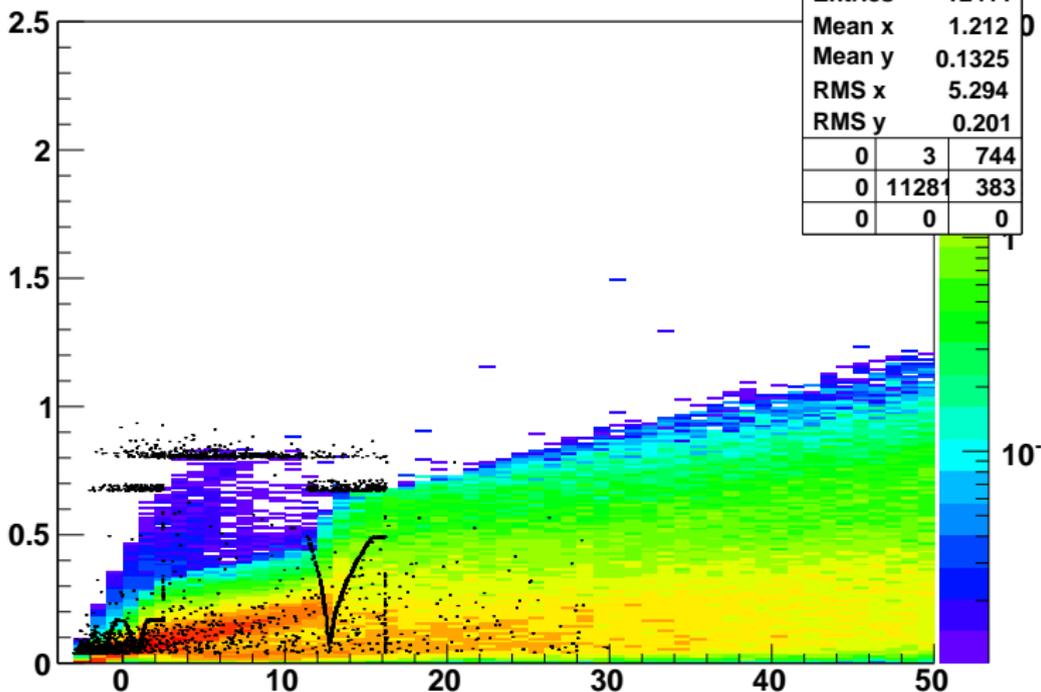
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Flux
Characteristics

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Beam
Systematics

ν_{μ} production radius (m) versus $V_z(m)$, $E_{\nu} = 1.5-2.5$ GeV



Origin of Neutrinos (ND570)

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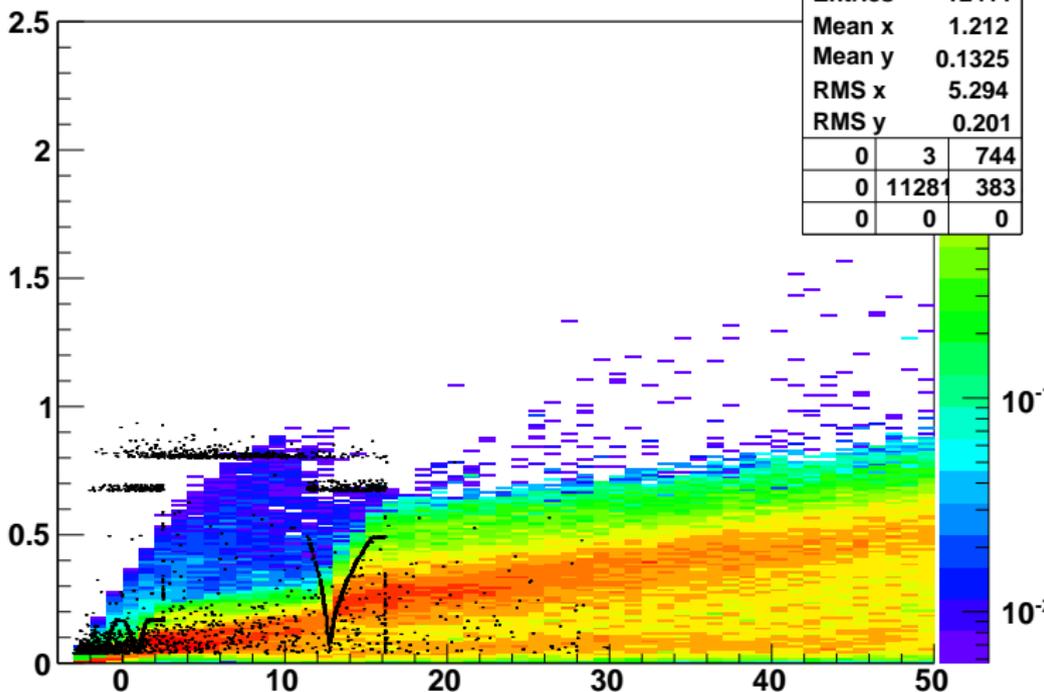
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Flux
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Extrapolation

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ν_{μ} production radius (m) versus $V_z(m)$, $E_{\nu} = 2.5-3.5$ GeV



Origin of Neutrinos (ND570)

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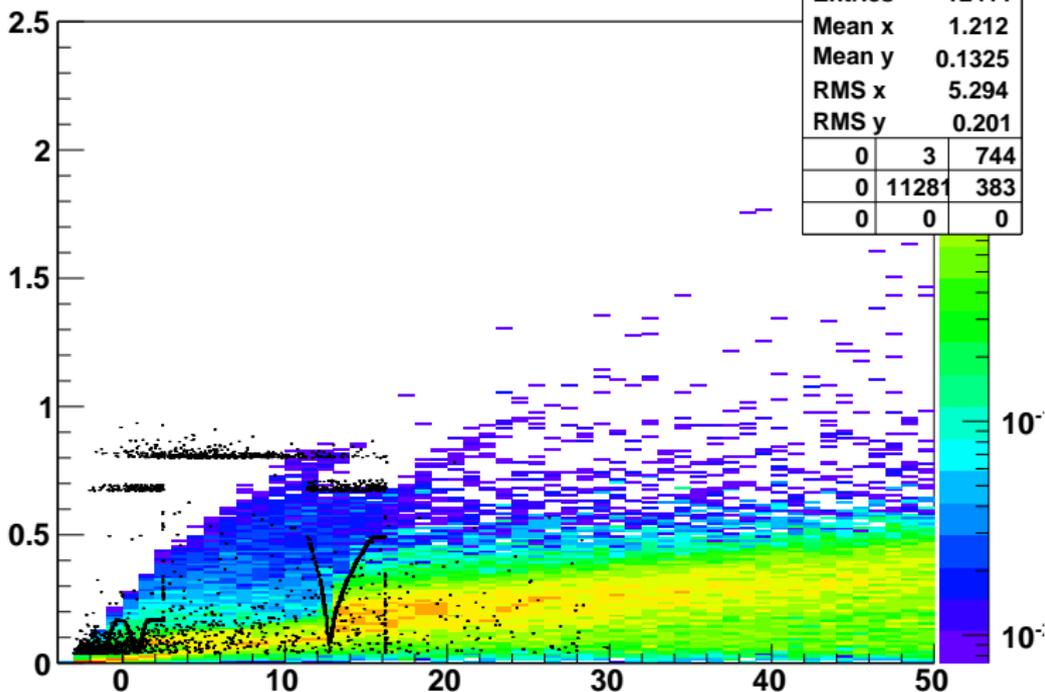
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Flux
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ν_{μ} production radius (m) versus $V_z(m)$, $E_{\nu} = 3.5-5.0$ GeV



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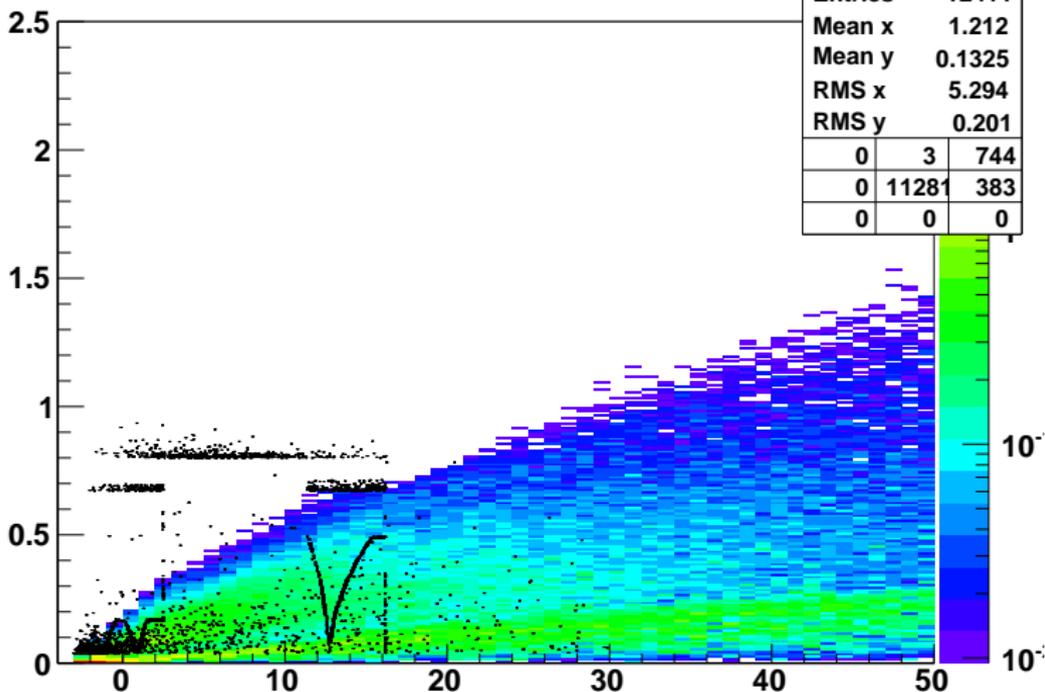
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Flux
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Systematics

ν_{μ} production radius (m) versus $V_z(m)$, $E_{\nu} = 5.0-10.0$ GeV



Origin of Neutrinos (ND570)

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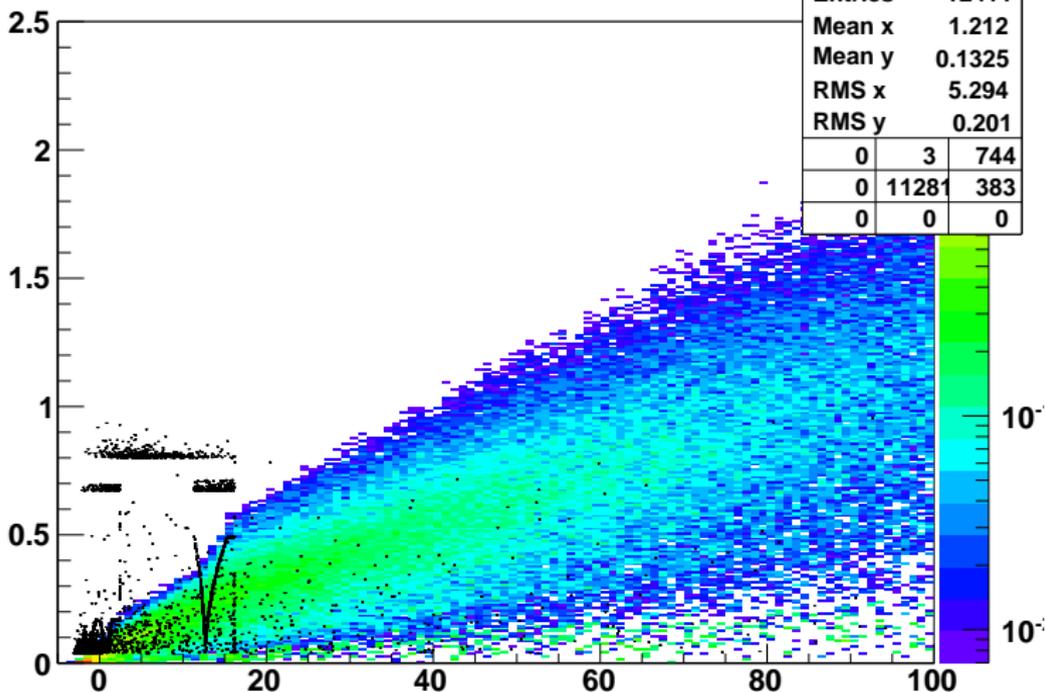
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Flux
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ν_{μ} production radius (m) versus $V_z(m)$, $E_{\nu} > 10.0$ GeV



Profile of ν Z decay location (1300km)

Neutrino
Beam Flux in
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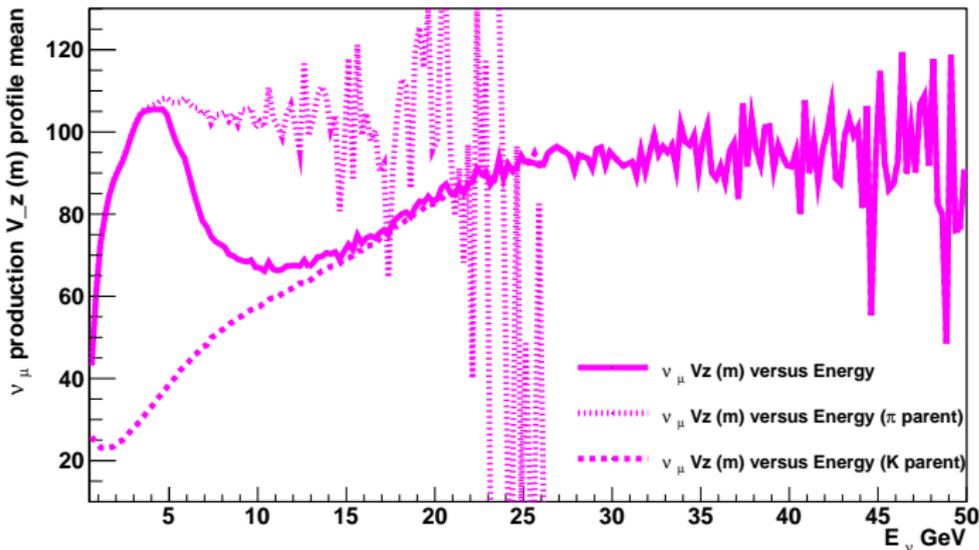
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ν_{μ} events at FD (1300km)



Center of decay channel is at $Z \sim 110\text{m}$.

N/F Ratios at Various Locations

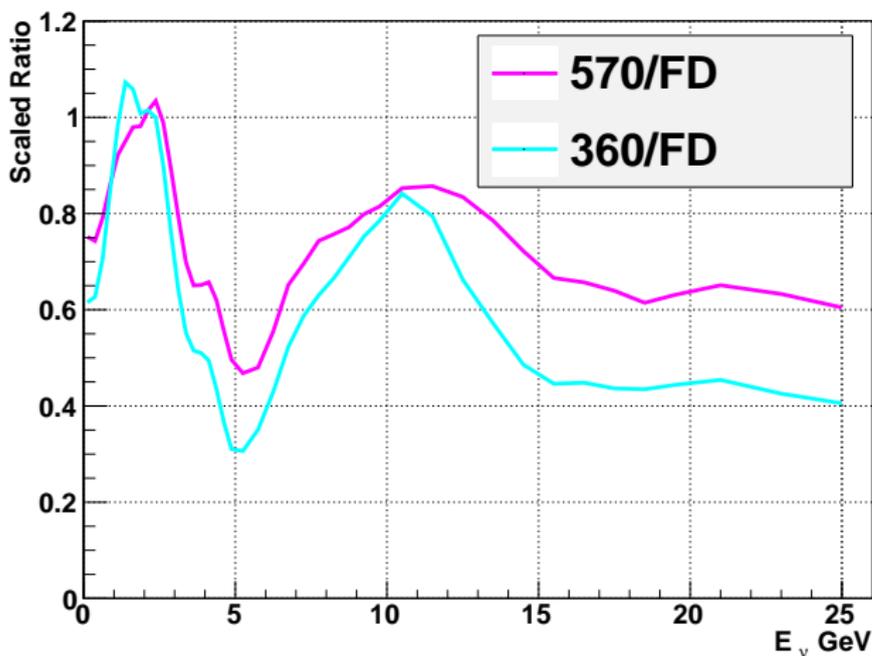
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Flux
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N/F
Extrapolation

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BL scaled from center of decay channel ($\sim 110\text{m}$).

N/F Ratios at Various Locations

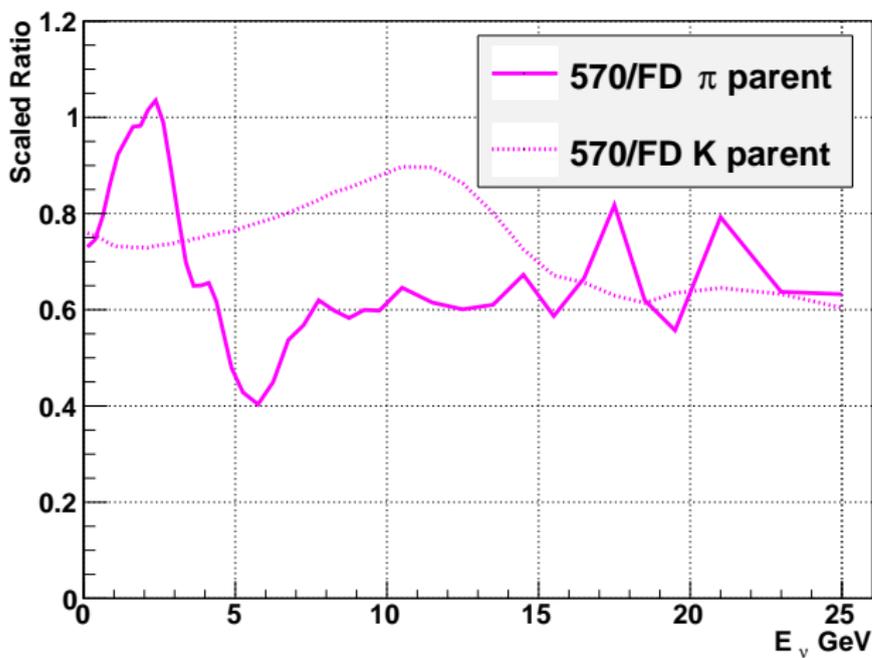
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Characteristics

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0-5 GeV N/F dominated by π . $> 10\text{ GeV}$ dominated by K^+

N/F Ratios at Various Locations

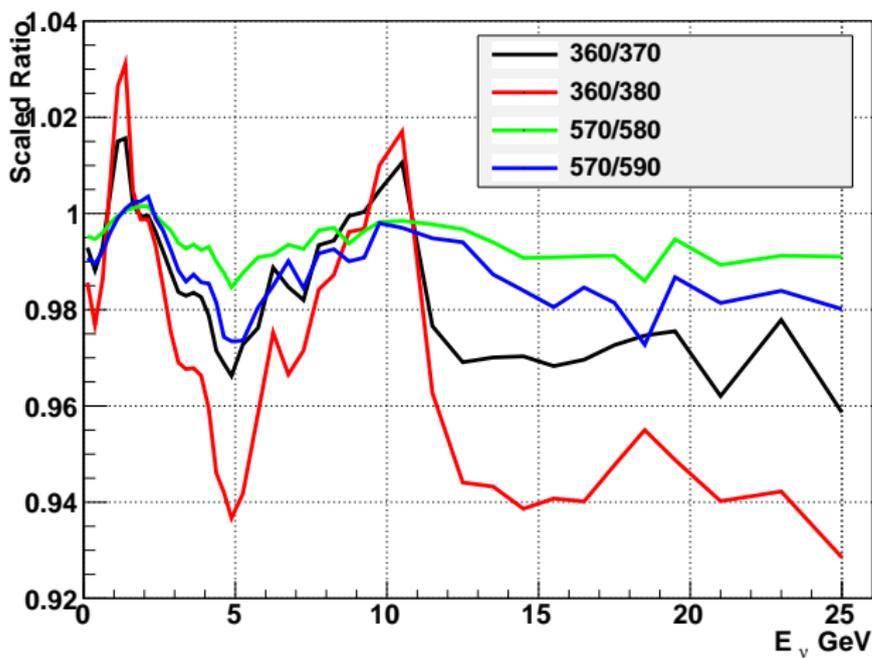
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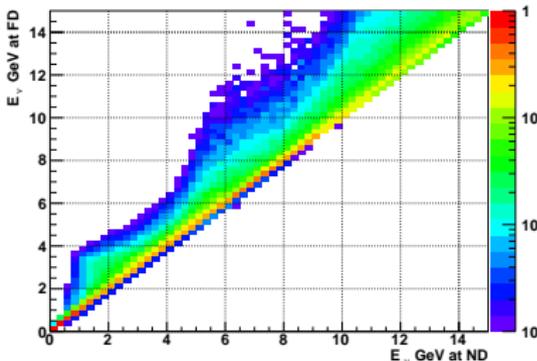


The same N/F effects on a smaller scale 10m apart

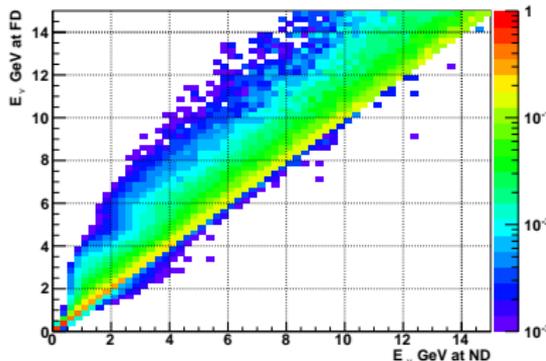
Beam Matrix: $\phi_i^{FD} = \sum_j \underbrace{(\phi_{ij}^{FD} / \phi_j^{ND})}_{\text{Beam Matrix}} \phi_j^{ND}$

ND360

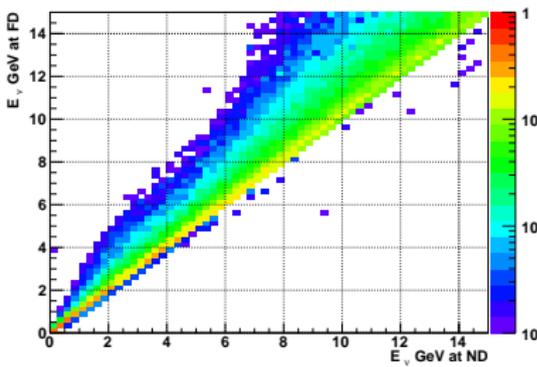
Normalized FD/ND ν_μ flux ratio



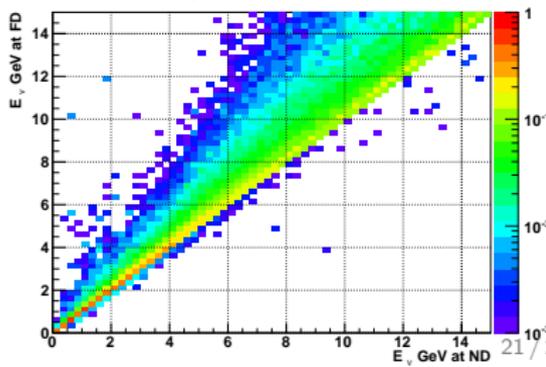
Normalized FD/ND $\bar{\nu}_\mu$ flux ratio



Normalized FD/ND ν_e flux ratio



Normalized FD/ND $\bar{\nu}_e$ flux ratio



Neutrino
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Flux
Characteristics

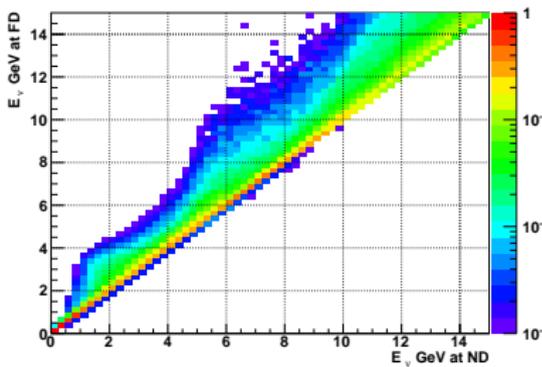
N/F
Extrapolation

Beam
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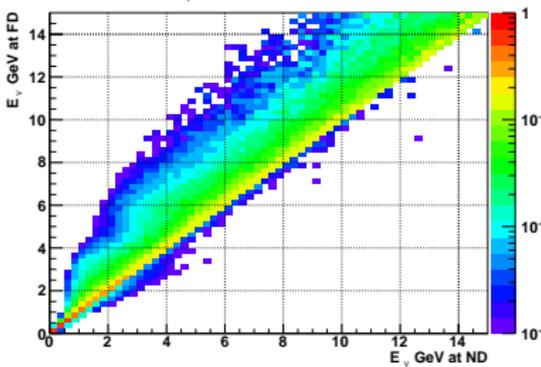
Beam Matrix: $\phi_i^{FD} = \sum_j \underbrace{(\phi_{ij}^{FD} / \phi_j^{ND})}_{\text{Beam Matrix}} \phi_j^{ND}$

ND380

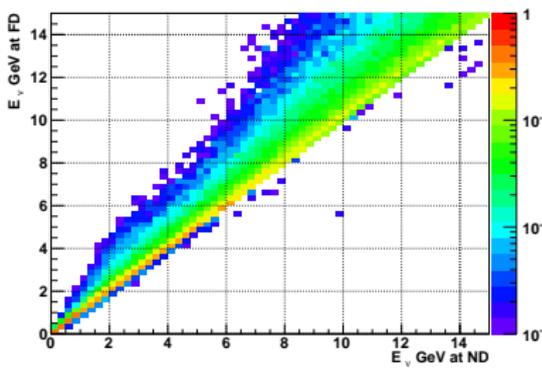
Normalized FD/ND ν_μ flux ratio



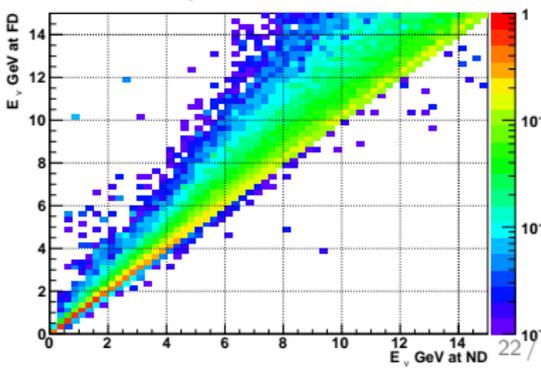
Normalized FD/ND $\bar{\nu}_\mu$ flux ratio



Normalized FD/ND ν_e flux ratio



Normalized FD/ND $\bar{\nu}_e$ flux ratio



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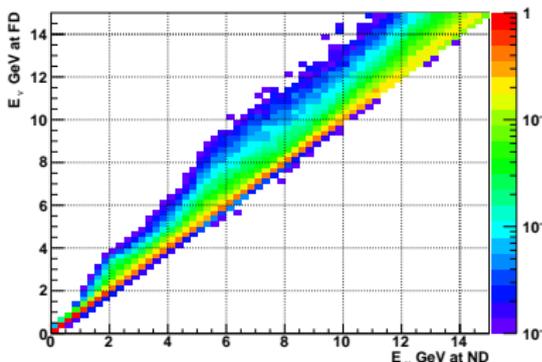
N/F
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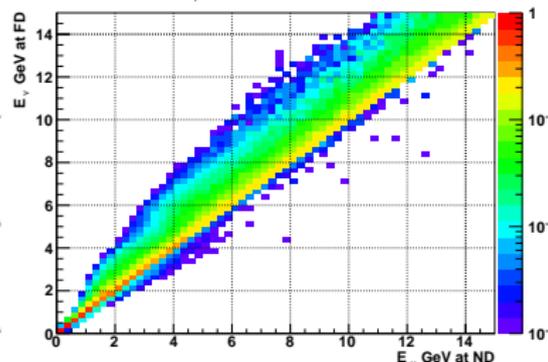
Beam Matrix: $\phi_i^{FD} = \sum_j \underbrace{(\phi_{ij}^{FD} / \phi_j^{ND})}_{\text{Beam Matrix}} \phi_j^{ND}$

ND570

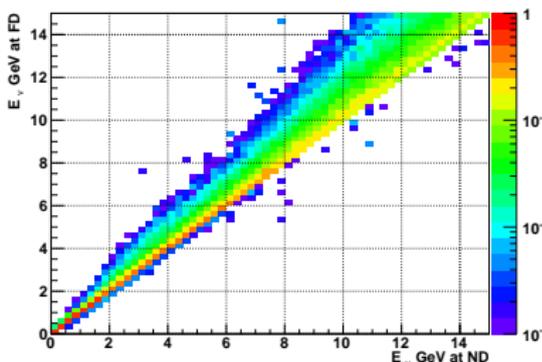
Normalized FD/ND ν_μ flux ratio



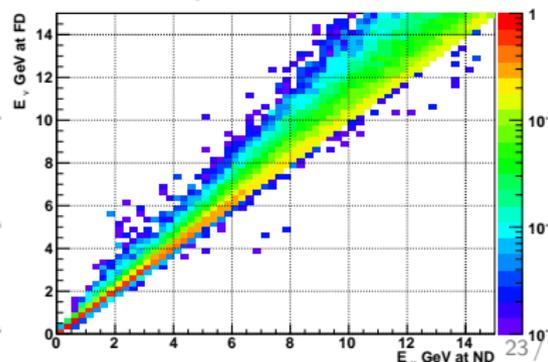
Normalized FD/ND $\bar{\nu}_\mu$ flux ratio



Normalized FD/ND ν_e flux ratio



Normalized FD/ND $\bar{\nu}_e$ flux ratio



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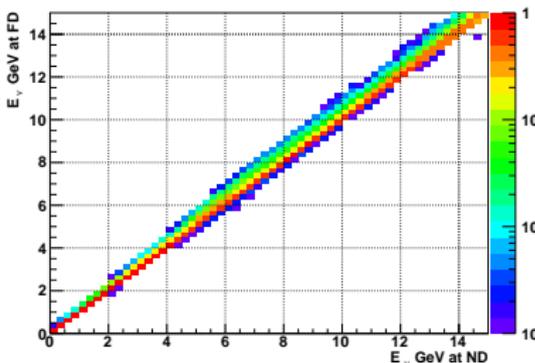
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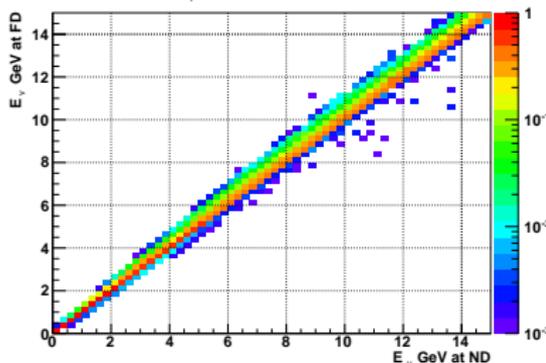
Beam Matrix: $\phi_i^{FD} = \sum_j \underbrace{(\phi_{ij}^{FD} / \phi_j^{ND})}_{\text{Beam Matrix}} \phi_j^{ND}$

ND2km

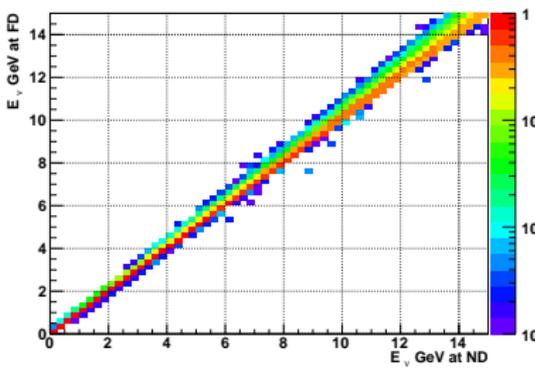
Normalized FD/ND ν_μ flux ratio



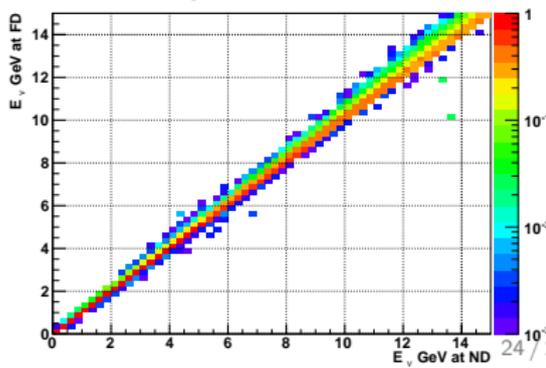
Normalized FD/ND $\bar{\nu}_\mu$ flux ratio



Normalized FD/ND ν_e flux ratio



Normalized FD/ND $\bar{\nu}_e$ flux ratio



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Beam Systematics in ND360 and ND570

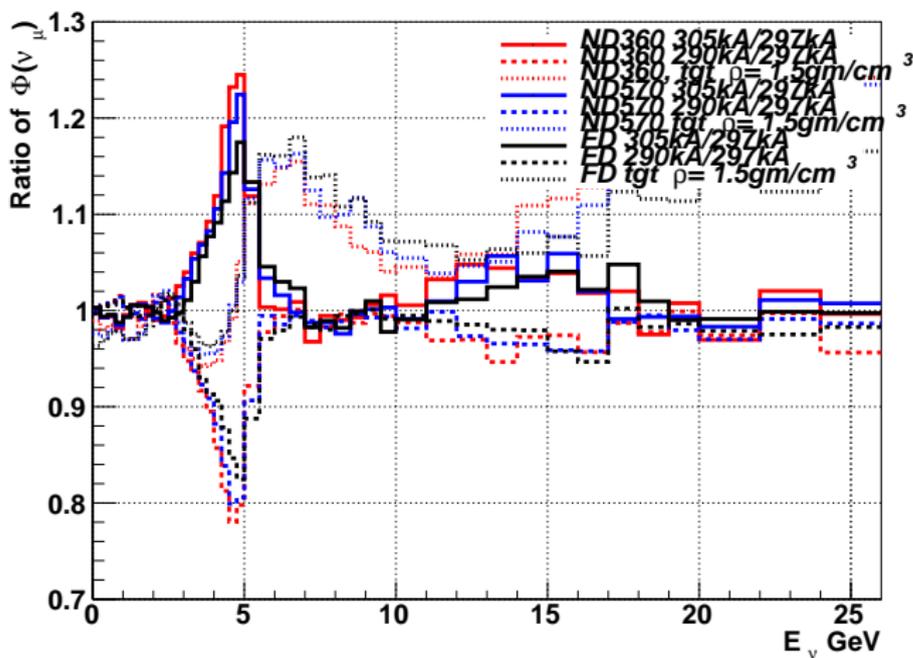
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The nearer the detector - the *more sensitive* to focusing effects

Beam Systematics in ND360 and ND570

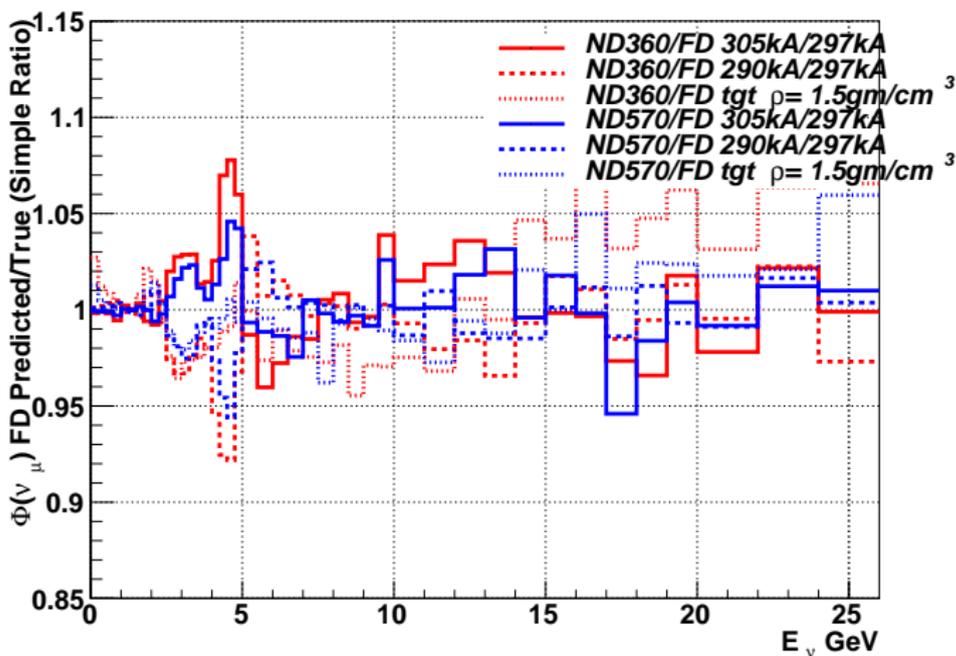
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Residual N \rightarrow F discrepancy using simple F/N ratio

Beam Systematics in ND360 and ND570

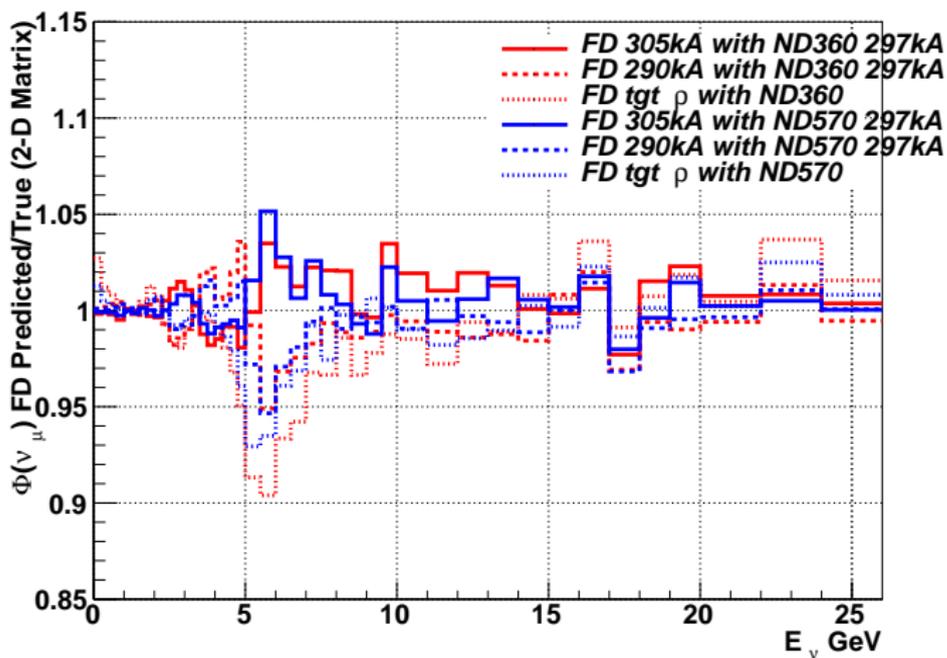
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Residual N \rightarrow F discrepancy using 2-D matrix extrapolation

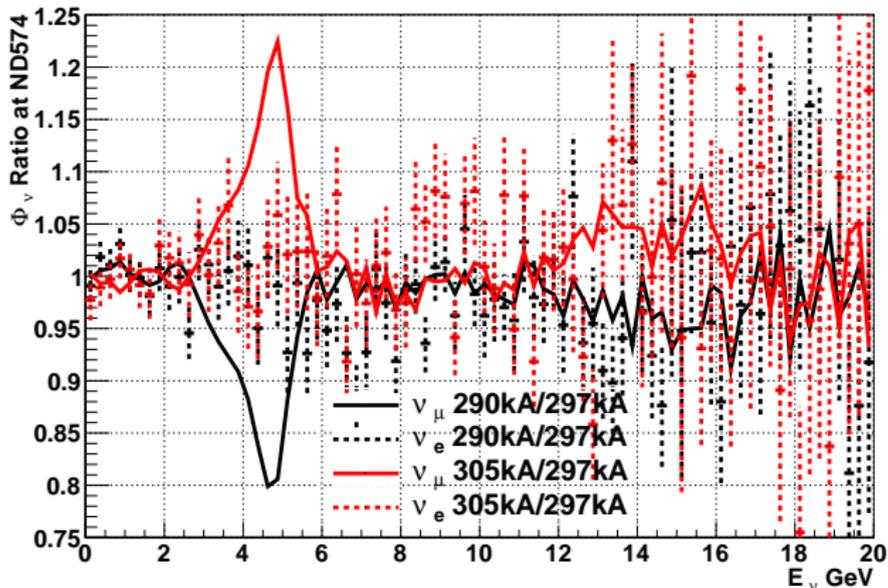
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Focusing effects have smaller effects on $\Phi(\nu_e)$